STABLE ISOTOPES $\delta^{18}O$ AND δD IN THE OLENTANGY RIVER

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Abstract

Natural bodies of water have varying isotopic signatures of $\delta^{18}O$ and δD depending on their geographic location and the surrounding climate. These stable isotopes can be used to fingerprint water samples, allowing scientists to describe characteristics of incoming precipitation and terrestrial bodies of water. The Global Meteoric Water Line (GMWL) describes the ratio of δD to $\delta^{18}O$ of precipitation from around the world. The equation of this line is $\delta D = 8 * \delta^{18}O + 10$. Every location has a Local Meteoric Water Line (LMWL) that deviates from GMWL, describing its precipitation. This project investigated the isotopic signature of the Olentangy River in Columbus, Ohio. Samples were collected from December, 2017 to February, 2018. Samples were collected with no headspace and transferred into 2 mL vials for isotopic analysis. Isotopes $\delta^{18}O$ and δD were analyzed using the Picarro Wavelength Scanned-Cavity Ring Down Spectroscopy Analyzer for Isotopic Water-Model L1102-i. River samples were standardized by internal lab $\delta^{18}O$ and δD standards from Colorado, Nevada, Ohio, and Florida. Results were compared to the central Ohio LMWL, which was developed by the Anne Carey research group. The trendline describing the Olentangy river samples was $y = 6.77x – 0.655$ ($R^2 = 0.99$), which had a similar slope but a lower intercept than the central Ohio LMWL. Samples strongly reflect the local precipitation, showing minimal amounts of evaporation during the winter months.

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Introduction

Natural bodies of water have isotopic signatures depending on their location and the nature of the water cycle in the surrounding environment. Stable isotopes are isotopes that don't go through radioactive decay like oxygen-18 and hydrogen-2 (also called deuterium).

Natural bodies of water have isotopic signatures of $\delta^{18}O$ and δD. These stable isotopes of oxygen and hydrogen can be used as 'fingerprints' that describe the contents of precipitation and bodies of water. The Global Meteoric Water Line (GMWL) demonstrates the ratio of $\delta^{18}O$ and δD precipitation around the world (Craig, 1961). Local Meteoric Water Lines (LMWL) describe this same ratio on a smaller spatial scale. The of $\delta^{18}O$ and δD ratios =, ^{18}O:/ ^{16}O and ^{2}H:^{1}H respectively, are compared to the Vienna Standard Mean Ocean Water (VSMOW) which is the global standard for water ^{18}O:^{16}O and ^{2}H:^{1}H ratios.

The equation for the GMWL is $\delta D = 8 * \delta^{18}O + 10$. By collection of samples from a body of surface water, the isotopic composition can be determined and a trendline can be made. Sample results from a surface body of water, like a river, can be compared to the LMWL to see how the ratios in precipitation differ from the ratios in river water. So, what does the trendline for the Olentangy River in Columbus, Ohio look like? It was hypothesized that the isotopic content of the river would be similar to the LMWL due to expected low evaporation rates during the winter months.

Methods

Sample Collection

River samples were collected from the end of November 2017 through February 2018. The samples were collected along the Olentangy River, upstream from the Lane Avenue bridge in Columbus, Ohio (Figure 1). This location is at 40.006989 latitude and -83.021768 longitude. A large, clean LDPE plastic bottle was used to collect water samples. The bottle and cap were rinsed out with river water before the sample was collected. To get the sample, the bottle was placed in a position where it would be submerged directly below the water surface and into the current. The bottle was pointed away from standing position, to avoid contamination from shoes, and tilted upward until water could flow into the bottle, filling it completely. Once the bottle was filled, the cap was also filled with water and the bottle was quickly sealed to prevent air from entering the container.

Sample Preparation

The collected water samples were taken into the lab and were prepared to be tested for isotopes. Water from the sample bottle was transferred directly into 2ml vials for the spectroscopy analyzer. A sample would be stored in a refrigerator if the sample could not be run immediately after collection.

Finding Results

Stable isotopes found in rainwater were collected and compared to the internal laboratory standards to be corrected and compared to the Local Meteoric Water Line (LMWL) and the Global Meteoric Water Line (GMWL). The stable isotopes found in river water would also undergo this process to see how the isotopes in rain water and river water compare to each other and the LMWL. The machine used to determine the stable isotopes in the sample in the Picarro Wavelength Scanned-Cavity Ring Down Spectroscopy Analyzer for Isotopic Water Model L1102.

Results

After the results of each sample were graphed, a linear trend could be seen (Table 1). The equation for this line was $y= 6.77x – 0.655$ with an R^2 value of 0.9999. The trendline made from this equation was compared to the LMWL ($y= 7.57x + 6.0586$). The points, which represent data from each sample, fell on the LMWL. The trendline, as a whole, deviates from the LMWL slightly with a smaller slope. Samples C, D, E, G, H, and I, all have $\delta^{18}O$ values that range between -9.00‰ and -10.00‰. These samples have δD values between -60.0‰ and -70.0‰. Samples A and B have noticeably different values compared to the others. The $\delta^{18}O$ and δD values were -8.30‰ and -57.0‰ respectively in Sample A. Sample B values were even lower at -7.19‰ and -49.2‰. (Figure 2).

Discussion

Reasons for Similarities

In nature, water molecules have different combinations of heavy oxygen and hydrogen isotopes. These isotopes tend to stay bonded together in equilibrium at moderate temperatures according to general thermodynamic principles (Gat, 1996). The contents of precipitation and surface water are correlated due to the recycling of evaporated water (Dutton, 2005). When the water molecules go from a liquid state to a gas state and vice versa, the molecules will start to separate by weight through varying levels of fractionation. The lighter water molecules that contain less of these isotopes would evaporate before the heavier molecules do (Dansgaard, 1964). This process would cause the composition of stable isotopes $\delta^{18}O$ and δD in precipitation and river water to vary. The fact that the trendline generated from the sample results was very similar to the LMWL showed that both the local precipitation and the river water were very similar in isotopic composition. This implies that any evaporation that had taken place over the winter months had not significantly affected the amount of isotopes that were present in the atmosphere. The lack of evaporation during this time was likely due to the generally cool winter air which provides ideal conditions for low evaporation rates. Some evaporation did occur during this time though as represented by the slight decrease in slope as shown in (Figure 3.).

Anomaly Explanation

The amounts of $\delta^{18}O$ and δD were different in Samples A and B compared to the other samples because there was less deviation from the internal lab standards in these samples. Since all the samples had negative values, the amounts of these stable isotopes within the samples were less than the set standard. (Gat, 1996). The smaller deviation implies that Samples A and B contained more of these isotopes. Unlike the other samples, Samples A and B were collected around periods of rain. Sample A was collected a day after it had rained and Sample B was collected several hours after it had rained. This would have allowed water of different isotopic composition to enter the river and be included in the samples.

Conclusions

Due to low evaporation rates and similar isotopic compositions, the contents of the river must primarily originate from precipitation, as shown by similarities from the LMWL and the Olentangy River isotopic composition trendline. The timing of sample collection after rainfall can affect the ratio of isotopes present in the sample.

Future Research

Studying how isotopic data would change if water samples were collected during other times of the year, especially summer, could be a potential next step in this study. Comparing these findings to the heavy isotopes in other rivers around the Columbus area like the Scioto could reveal additional information about the surrounding environment. What would the similarities and differences between the rivers imply? What should be expected?

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Appendix

Figure 1. A photograph of the sample site in March 2018 taken from the Lane Avenue Bridge. (Photograph taken by Zuri Brooks)

SAMPLE	DATE	NORMALIZED $\delta^{18}O$ (‰)	NORMALIZED δD (‰)
A	11/30/17	-8.30	-57.0
B	12/7/17	-7.19	-49.2
C	1/25/17	-9.96	-69.1
D	1/26/17	-9.80	-67.0
E	1/31/18	-9.22	-63.6
G	2/8/18	-9.85	-66.5
H	2/13/18	-9.77	-66.6
I	2/15/18	-9.79	-66.1

Table 1. Data from samples A-E and G-I. The equation for the trendline and the R^2 value are shown in Figure 2.

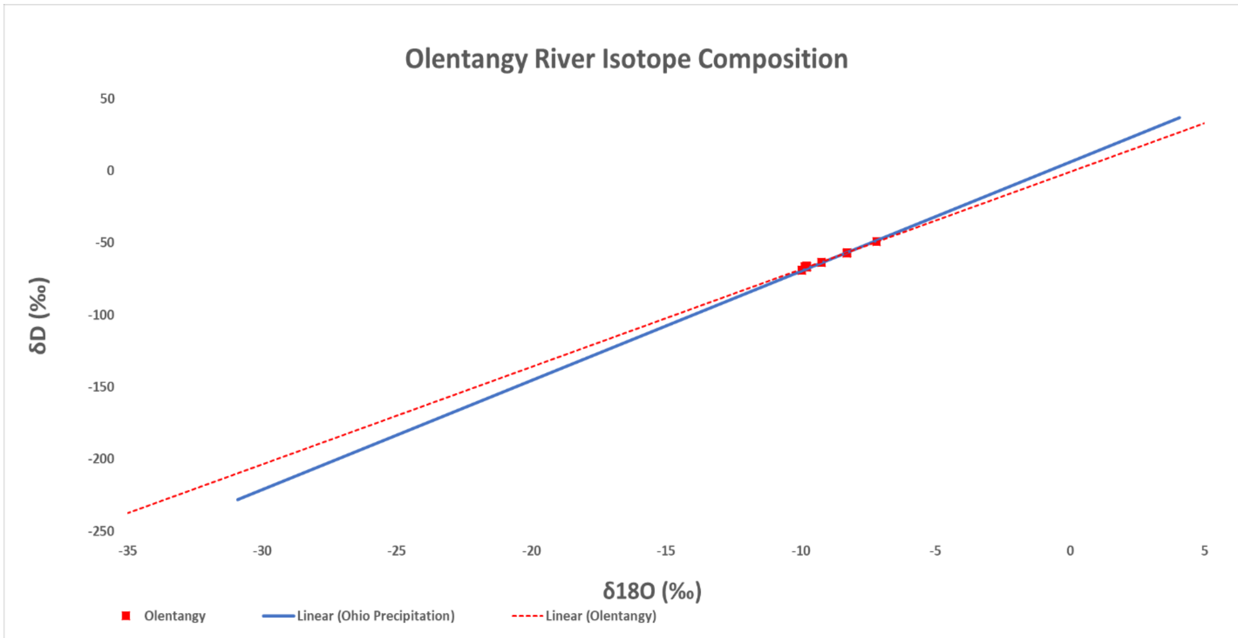

Figure 2. Stable isotope data for $\delta^{18}O$ and δD from the Olentangy River through the winter months of 2017 and 2018. The equation for this line is $y= 6.7692x – 0.655$ and an R^2 value of 0.9999. The R^2 value represents how well the trendline fits within the points. The slopes of the lines vary, but the sample points all fall on the LMWL whose equation is $y= 7.5733x – 6.0586$ and whose R^2 value is 0.9715. The LMWL was provided by Dr. Carey's research group.